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Section-I: General Ability

1. Functions F(a,b) and G(a,b) are defined as follows:
F(a,b) = $(a-b)^2$ and G(a,b) =|a-b|, where |x| represents the absolute value of x.
What would be the value of G(F(1,3), G(1,3))?
(A) 2 (B) 4 (C) 6 (D) 36

Key: (A)

Exp: Given,

$$F(a,b)=(a-b)^2 \text{ and } G(a,b)=|a-b|$$
$$\Rightarrow F(1,3)=(1-3)^2;\Rightarrow G(1,3)=|1-3|$$
$$\Rightarrow F(1,3)=4 \quad ;\Rightarrow G(1,3)=2$$
$$\therefore G\big(F(1,3),G(1,3)\big)=G(4,2)\rightarrow\left[\because F(1,3)=4\&G(1,3)=2\right]$$
$$=|4-2|\rightarrow\left[\because G(a,b)=|a-b|\right]$$
$$\Rightarrow G\big(F(1,3),G(1,3)\big)=2$$

2. "Since you have gone off the _____, the _____ sand is likely to damage the car."
The words that best fill the blanks in the above sentence are
(A) course, coarse (B) course, course (C) coarse, course (D) coarse, coarse

Key: (A)

3. "A common misconception among writers is that sentence structure mirrors thought; the more _____ the structure, the more complicated the ideas."
The word that best fills the blank in the above sentence is
(A) detailed (B) simple (C) clear (D) convoluted

Key: (D)

4. For what values of k given below is $\frac{(k+2)^2}{k-3}$ an integer?
(A) 4,8,18 (B) 4, 10, 16 (C) 4,8,28 (D) 8, 26, 28

Key: (C)

Exp: Actually we can find an infinite no. of values of k, for which $\frac{(k+2)^2}{k-3}$ to be an integer

From the given choices;

If $k=4$, then $\frac{(k+2)^2}{k-3}=\frac{(4+2)^2}{4-3}=36\rightarrow$ integer.

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If $k=8$, then $\frac{(k+2)^2}{k-3}=\frac{(8+2)^2}{8-3}=\frac{100}{5}=20\rightarrow$ integer

If k=28, then $\frac{(28+2)^2}{28-3}=\frac{(30)^2}{25}=\frac{30\times30}{25}=36\rightarrow$ integer.

5. The three roots of the equation f(x) = 0 are x = {-2, 0, 3}. What are the three values of x for which f(x-3) = 0?

(A) -5, -3, 0 (B) -2, 0, 3 (C) 0, 6, 8 (D) 1, 3, 6

Key: (D)

Exp: Given that;

X= -2, 0, 3 are the 3 roots of $f(x)=0$.

i.e., $f(-2)=0, f(0)=0$ and $f(3)=0$.

Now we should find the values of x for which

$f(x-3)=0\Rightarrow x-3=-2; x-3=0; x-3=3$

$\left[\because f(-2)=0; f(0)=0; f(3)=0\right]$

$\Rightarrow x=-2+3; x=3; x=6$

$\Rightarrow x=1,\ 3, 6$

6. A class of twelve children has two more boys than girls. A group of three children are randomly picked from this class to accompany the teacher on a field trip. What is the probability that the group accompanying the teacher contains more girls than boys?

(A) 0 (B) $\frac{325}{864}$ (C) $\frac{525}{864}$ (D) $\frac{5}{12}$

Key: (B)

Exp: Given, a class of 12 children has no two more boys than girls.

Let, the no.of girls $= x$

Then no.of boys $= x+2$

$\therefore x+(x+2)=12$

$\Rightarrow 2x=10$

$\Rightarrow x=5$

No.of Grils $=5$

No.of Boys $=7$

$\therefore$ Total no. of ways of selection of 3 children = ${}^{12}C_3\rightarrow n(s)$

Let A be the event that no. of girls are more than boys

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i.e. Case $\rightarrow$ (I) $\downarrow$ 3G & 0B (or) Case $\rightarrow$ (II) $\downarrow$ 2G & 1B [Two cases possible]

Favorable no. of ways of A $= {}^5C_3 \times {}^7C_0 + {}^5C_2 \times {}^7C_1$

$= 10 + 70 = 80 \left[\because {}^5C_2 = {}^5C_3 = 10\right]$

$$\therefore \text{Prob}(A) = \frac{n(A)}{n(S)} = \frac{80}{{}^{12}C_3} = \frac{80 \times 3!}{12 \times 11 \times 10}$$

$$= \frac{80 \times 6}{12 \times 11 \times 10} = \frac{8}{22} = \frac{4}{11} \simeq 0.3636 \simeq \frac{325}{864}$$

$$\Rightarrow \text{Req Prob} = \frac{325}{864}$$

7. An e-mail password must contain three characters. The password has to contain one numeral from 0 to 9, one upper case and one lower case character from the English alphabet. How many distinct passwords are possible?

(A) 6,760 (B) 13,520 (C) 40,560 (D) 1,05,456

Key: (C)

Exp: We know that;

Total no. of digits $= [0,1,2,....9]$

Total no. of upper case English alphabets $= 26[A, B, C, ..., Z]$

Total no. of lower case English alphabets $= 26[a, b, c, ..., z]$

$\therefore$ No. of ways of selecting a digit out of $10 = {}^{10}C_1 = 10$

No. of ways of selecting an upper case alphabet $= {}^{26}C_1 = 26$

No. of ways of selecting an lower case alphabet $= {}^{26}C_1 = 26$

$\therefore$ Permutation = selection + arrangement

$\therefore$ Total no.of distinct passwords $= 10 \times 26 \times 26 \times 3!$

$10 \rightarrow \{1, 2, 3, ..., 9\}$; $26 \rightarrow \{A, B, ..., Z\}$; $26 \rightarrow \{a, b, ..., z\}$; $3!$ = arrangement of 3 things $\downarrow$ arrangement

Selection

$= 6760 \times 6 \left[\because 3! = 6\right]$

$= 40,560$

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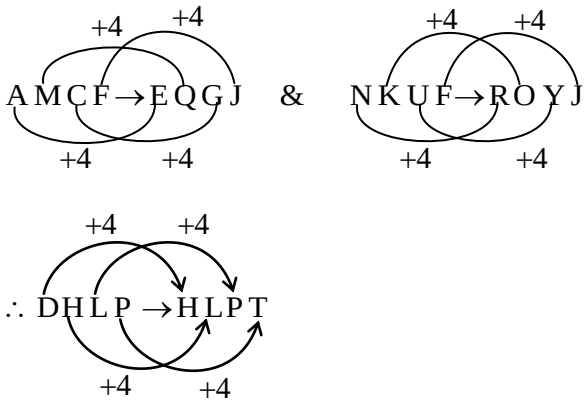
8. In a certain code, AMCF is written as EQGJ and NKUF is written as ROYJ. How will DHLP be written in that code?

(A) RSTN (B) TLPH (C) HLPT (D) XSVR

Key: (C)

Exp: Given



9. A designer uses marbles of four different colours for his designs. The cost of each marble is the same, irrespective of the colour. The table below shows the percentage of marbles of each colour used in the current design. The cost of each marble increased by 25%. Therefore, the designer decided to reduce equal numbers of marbles of each colour to keep the total cost unchanged. What is the percentage of blue marbles in the new design?

Blue	Black	Red	Yellow
40%	25%	20%	15%

(A) 35.75 (B) 40.25 (C) 43.75 (D) 46.25

Key: (C)

Exp: Assume that,

Total no. of marbles = 100

C.P of 1 marble =Rs 100

Total C.P of 100 marbles $=100\times100$

New cost price of 1 marble = Rs 125 [Given]

No. of marbles with new price $=\dfrac{100\times100}{125}=80$

$\therefore$ No.of reduced marbles $=100-80=20\left[\underset{\text{Blue}}{5}+\underset{\text{Black}}{5}+\underset{\text{Red}}{5}+\underset{\text{Yellow}}{5}=20\right]$

Now; the no. of blue marbles = 40-5=35

Total no. of marbles =10-20=80

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$\therefore$ % of blue marbles in new design $= \left[\frac{35}{80}\times 100\right]\%$

$= \left[\frac{35\times 5}{4}\right]\%$

$= 43.75\%$

10. P,Q,R and S crossed a lake in a boat that can hold a maximum of two persons, with only one set of oars. The following additional facts are available.

(i) The boat held two persons on each of the three forward trips across the lake and one person on each of the two return trips.

(ii) P is unable to row when someone else is in the boat.

(iii) Q is unable to row with anyone else except R.

(iv) Each person rowed for at least one trip.

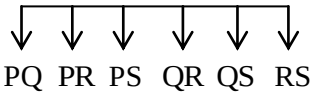
(v) Only one person can row during a trip.

Who rowed twice?

(A) P (B) Q (C) R (D) S

Key: (C)

Exp: Section of 2 persons out of 4 (P, Q, R, S), i.e., ${}^4C_2$ = 6ways

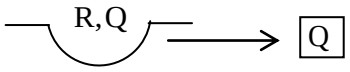


From the fact (i), there are $\rightarrow$ [3 forward trips [Two person can travel]; 2 returned trips [only 1 person travel]]

From the facts (ii) and (iii); P and Q should not travel.

To satisfy (iv) fact; only Q and R should travel in 1st trip.

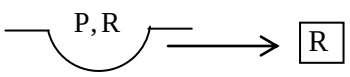
First trip: Q Rowed in forward trip



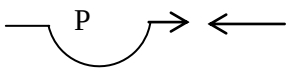
R Rowed in return trip

Second trip: In 2nd trip only R & P should travel.

R Rowed in forward trip



P Rowed in return trip



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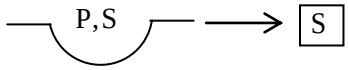
Third trip : In 3rd trip only P & S will travel

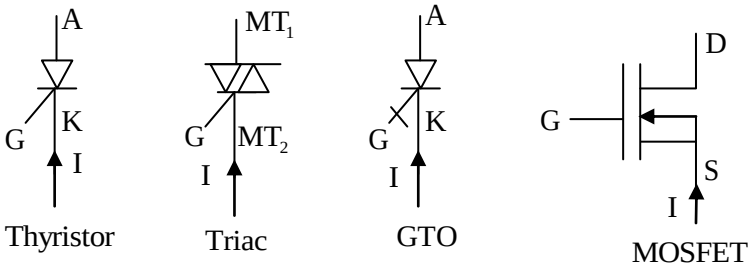


S must rowed in forward trip $\left[\because \text{From (ii) fact}\right]$

$\therefore$ R rowed twice.

Section-II: Electrical Engineering

1. Four power semiconductor devices are shown in the figure along with their relevant terminals. The devices (s) that can carry dc current continuously in the direction shown when gated appropriately is (are)

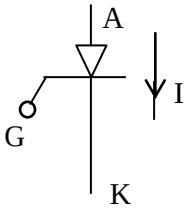


(A) Triac only
(B) Triac and MOSFET
(C) Triac and GTO
(D) Thyristor and Triac

Key: (B)

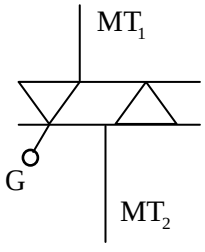
Exp: SCR: conducts only from anode to cathode

Triac:



(1) Triac is combination of two anti parallel SCRs

Triac



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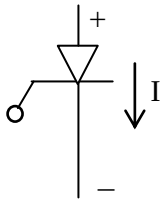
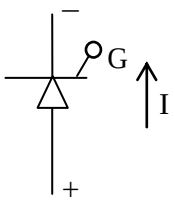
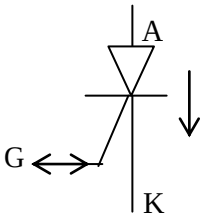
(2) When MT_1 is + ve & MT_2 is – ve



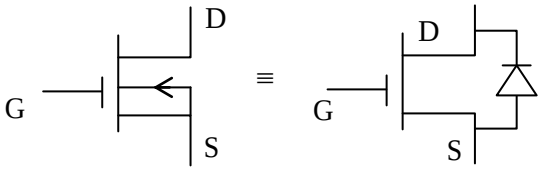
(3) When MT_1 is – ve & MT_2 is + ve



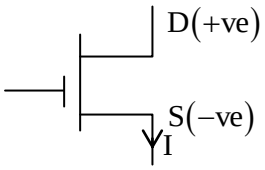
GTO: GTO conducts only from anode to cathode



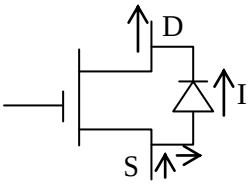
MOSFET



(1) When D is + ve & S is –ve, diode is OFF



(2) When D is –ve & S is +ve, diode is ON



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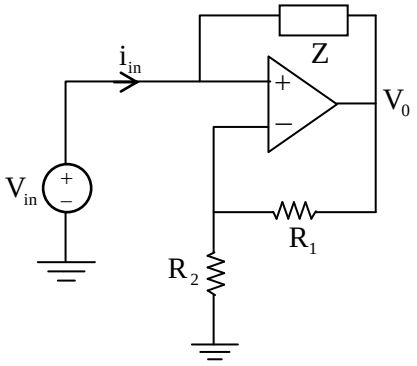
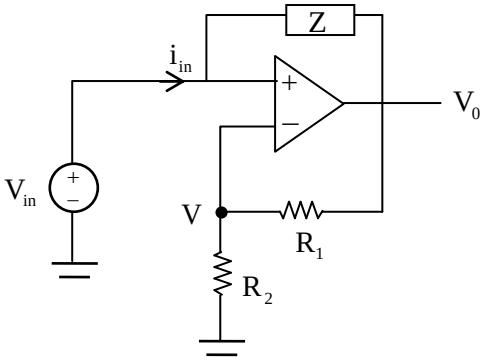
2. The op-amp shown in the figure is ideal. The input impedance $\frac{v_{in}}{t_{in}}$ is given by



(A) $Z\frac{R_1}{R_2}$ (B) $-Z\frac{R_2}{R_1}$ (C) Z (D) $-Z\frac{R_1}{R_1+R_2}$

Key: (B)

Exp: Given op- Amp is ideal



By virtual ground concept

$V_{in} = V$

$i_{in} = \frac{V_{in} - V_0}{Z}$

By voltage divider principle

$V_{in} = V = \frac{V_0 \times R_2}{R_1 + R_2}$

$V_0 = V_{in}\left[1 + \frac{R_1}{R_2}\right]$

$i_{in} = \frac{V_{in} - V_{in} - V_{in}\frac{R_1}{R_2}}{Z} = -V_{in}\frac{R_1}{ZR_2}$

$\frac{V_{in}}{i_{in}} = -Z\frac{R_2}{R_1}$

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3. Two wattmeter method is used for measurement of power in a balanced three phase load supplied from a balanced three phase system. If one of the wattmeters reads half of the other (both positive), then the power factor of the load is

(A) 0.532 (B) 0.632 (C) 0.707 (D) 0.866

Key: (D)

Exp: $\rightarrow$ In two Wattmeter of power measurement we know

$$\phi = \tan^{-1}\left[\frac{\sqrt{3}(\omega_1 - \omega_2)}{\omega_1 + \omega_2}\right]\left(\text{well known standard formula}\right)$$

$\rightarrow$ It is given that one meter reads half of the other

$$\Rightarrow \omega_2 = \frac{\omega_1}{2}\left(\text{or we can take } \omega_1 = \frac{\omega_2}{2}\right)$$

$$\Rightarrow \phi = \tan^{-1}\left[\frac{\sqrt{3}\left(\omega_1 - \frac{\omega_1}{2}\right)}{\left(\omega_1 + \frac{\omega_1}{2}\right)}\right]$$

$$\Rightarrow \phi = \tan^{-1}\left[\frac{\sqrt{3}\left(\frac{\omega_1}{2}\right)}{3\left(\frac{\omega_1}{2}\right)}\right]$$

$$\Rightarrow \phi = \tan^{-1}\frac{1}{\sqrt{3}} \Rightarrow \phi = 30^\circ$$

$\rightarrow$ power factor $= \cos\phi$

$$= \cos 30^\circ = \frac{\sqrt{3}}{2} = 0.866$$

4. The graph of a network has 8 nodes and 5 independent loops. The number of branches of the graph is

(A) 11 (B) 12 (C) 13 (D) 14

Key: (B)

Exp: $\rightarrow$ we know in a network

$$\ell = b - (n - 1)$$

Where ℓ : number of loops = 5 (given)

b : number of branches (to be found)

h : number of nodes = 8 (given)

$$\Rightarrow \ell = b - n + 1$$

$$\Rightarrow 5 = b - 8 + 1$$

$$\Rightarrow b = 12$$

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5. A continuous time input signal x(t) is an eigenfunction of an LTI system, if the output is

(A) kx(t), where k is an eigenvalue

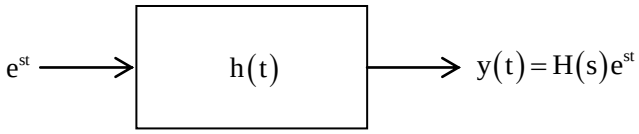
(B) $ke^{j\omega t}x(t)$, where k is an eigenvalue $e^{j\omega t}$ is a complex exponential signal

(C) x(t) $e^{j\omega t}$, where $e^{j\omega t}$ is a complex exponential signal

(D) $kH(\omega)$, where k is an eigenvalue and $H(\omega)$ is a frequency response of the system

Key: (A)

Exp: Consider for example eigen function, $x(t)=e^{st}$



Where H(s) is Laplace transform of h(t).

At specific $S=S_0$, $H(S_0)$ becomes a constant quantity.

Thus $y(t)=K.e^{st}$ or $K.x(t)$

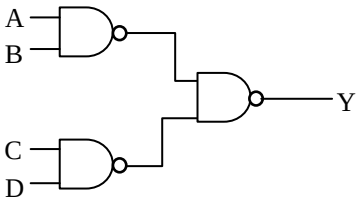
Where '**K' is eigen value.**

Thus option (A) is correct.

In option (B) extra frequency forms one getting generated at output which is not possible for LTI system.

Option (C) and Option (D) one also not the correct answer due to extra frequency term getting generated in output.

6. In the logic circuit shown in the figure, Y is given by



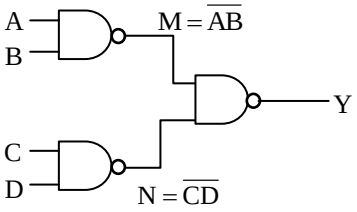
(A) Y=ABCD (B) Y = (A+B) (C+D) (C) Y=A+B+C+D (D) Y=AB+CD

Key: (D)

Exp: $y=\overline{\overline{M}\,\overline{N}}$

$y=\overline{\overline{AB}.\overline{CD}}$

$y=AB+CD$



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7. The value of the integral $\oint_C \frac{z+1}{z^2-4}\,dz$ in counter clockwise direction around a circle C of radius 1 with center at the point z = - 2 is

(A) $\frac{\pi i}{2}$ (B) $2\pi i$ (C) $-\frac{\pi i}{2}$ (D) $-2\pi i$

Key: (A)

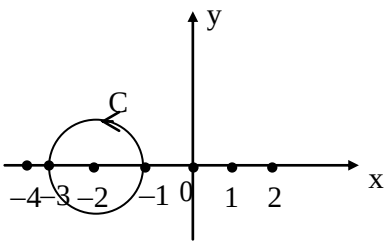
Exp: $\oint_C \frac{z+1}{z^2-4}dz$

$z^2-4=0$

$\Rightarrow z=\pm 2$

$\Rightarrow z=-2$ lies inside & $z=2$ lies outside 'C'

$\therefore$ By Cauchy's integral formula,



$$\oint_C \frac{z+1}{z^2-4}dz=\oint_C \frac{z+1}{(z+2)(z-2)}dz=\oint_C \frac{\left(\frac{z+1}{z-2}\right)}{z+2}dz$$

$$=2\pi i f(-2)$$

$$=2\pi i\left(\frac{-2+1}{-2-2}\right)=\frac{\pi i}{2}$$

8. Let f be a real valued function of a real variable defined as f(x) = x-[x], where [x] denotes the largest integer less than or equal to x. The value of $\int_{0.25}^{1.25} f(x)dx$ is _____(up to 2 decimal places).

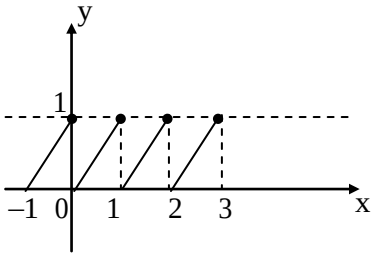
Key: (0.5)

Exp: We know that

$x=[x]+[x]$ where $[x]\rightarrow$ integral part of x,

$\Rightarrow x-[x]=\{x\}$ where $\{x\}\rightarrow$ fractional part of 'x'

$$\therefore \int_{0.25}^{1.25} f(x)dx=\int_{0.25}^{1.25}\{x\}dx$$



$$=\int_{0.25}^{1} x\,dx+\int_{1}^{1.25}(x-1)dx$$

$$=\frac{x^2}{2}\Big|_{0.25}^{1}+\left(\frac{x^2}{2}-x\right)\Big|_{1}^{1.25}$$

$$=\frac{1}{2}$$

$$=0.5$$

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9. The value of the directional derivative of the function $\phi(x,y,z) = xy^2 + yz^2 + zx^2$ at the point (2,-1, 1) in the direction of the vector p = i + 2j + 2k is

(A) 1 (B) 0.95 (C) 0.93 (D) 0.9

Key: (A)

Exp: $\nabla\phi = \bar{i}\frac{\partial\phi}{\phi x} + \bar{j}\frac{\partial\phi}{\partial y} + \bar{K}\frac{\partial\phi}{\partial z}$

$= \bar{i}\left(y^2 + 2zx\right) + \bar{j}\left(2xy + z^2\right) + \bar{k}\left(2yz + x^2\right)$

$\Rightarrow \nabla\phi_{(2,-1,1)} = 5\bar{i} - 3\bar{j} + 2\bar{k}$

Required directional deivative $= \left(5\bar{i} - 3\bar{j} + 2\bar{k}\right).\frac{\left(\bar{i} + 2\bar{j} + 2\bar{k}\right)}{\sqrt{1+4+4}}$

$= \frac{5-6+4}{3} = 1$

10. Match the transfer functions of the second order systems with the nature of the systems given below.

Transfer functions	Nature of system
P. $\frac{15}{s^2+5s+15}$	I. Overdamped
Q. $\frac{25}{s^2+10s+25}$	II. Critically damped
R. $\frac{35}{s^2+18s+35}$	III. Underdamped

(A) P-I, Q-II, R-III (B) P-II, Q-I, R-III (C) P-III, Q-II, R-I (D) P-III, Q-I, R-II

Key: (C)

Exp: $P \rightarrow \frac{15}{s^2+5s+15} = \frac{\omega n^2}{s^2 + \xi\omega_n s + \omega_n^2}$

$\omega_n = \sqrt{15}$

$2\xi\omega_n = 5$

$\xi = \frac{5}{2\sqrt{15}} < 1(\text{underdamped})$

$Q \rightarrow \frac{25}{s^2+10s+25} = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$

$\omega_n = \sqrt{25}$

$2\xi 5 = 10$

$\xi = 1(\text{critically damped})$

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$$R \to \frac{35}{s^2+18s+35} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$$

$$\omega_n = \sqrt{35}$$

$$2\xi\omega_n = 18$$

$$\xi = \frac{18}{2\sqrt{35}} > 1(\text{over damped})$$

P – III Q – II R – I

11. A 1000×1000 bus admittance matrix for an electric power system has 8000 non –zero elements. The minimum number of branches (transmission lines and transformers) in this system are _____ (up to 2 decimal places).

Key: (3500)

Exp: Given 1000×1000 bus matrix

$N = 1000$

Total root Buses $= 10^3 \times 10^3 = 10^6$

given no of non – zero elements $= 8000$

$$\text{Sparsity}(s) = \frac{\text{No of zero elements}}{\text{Total no of elements}}$$

$$= \frac{10^6 - 8000}{10^6} = 0.992$$

No of transmission lines and transformers

$$= \frac{N^2(1-s)-N}{2} = \frac{1000^2\times(1-0.992)-1000}{2} = 3500$$

12. A single phase 100kVA, 1000 V/100V. 50Hz transformer has a voltage drop of 5% across its series impedance at full load. Of this, 3% is due to resistance. The percentage regulation of the transformer at full load with 0.8 lagging power factor is

(A) 4.8 (B) 6.8 (C) 8.8 (D) 10.8

Key: A

Exp: Impedance $= 5\% = 0.05\text{pu} = Z_{pu}$

Resistance $= 3\% = 0.03\text{pu} = R_{pu}$

Reactance, $X_{pu} = \sqrt{z_{pu}^2 - R_{pu}^2}$

$$= \sqrt{0.05^2 - 0.03^2} = 0.04\text{pu}$$

$$VR(0.8\ \text{p.f lag}) = R_{pu}\cos\phi \pm X_{pu}\sin\phi$$

$$= 0.03\times0.8 + 0.04\times0.6$$

$$= 0.048\text{pu} = 4.8\%$$

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13. Let f be a real valued function of a real variable defined as $f(x) = x^2$ for $x \geq 0$, and $f(x) = -x^2$ for $x < 0$. Which one of the following statements is true?

(A) f(x) is discontinuous at x=0.

(B) f(x) is continuous but not differentiable at x=0

(C) f(x) is differentiable but its first derivative is not continuous at x=0.

(D) f(x) is differentiable but its first derivative is not differentiable at x=0.

Key: (D)

Exp: Given

$f(x) = x|x|$

$\Rightarrow f(x)$ in continuals & differentiable

$f'(x) = |x| + \frac{x|x|}{x}$

$= 2|x|$

$\Rightarrow f(x)$ is differentiable but its first derivative is not differentiable at x=0

14. A positive charge of 1nC is placed at (0, 0, 0.2) where all dimensions are in metres. Consider the x-y plane to be a conducting ground plane. Take $\in_0 = 8.85 \times 10^{-12}$ F / m. The Z component of the E field at (0, 0, 0.1) is closest to

(A) 899.18V/m (B) -899.18V/m (C) 999.09V/m (D) -999.09 V/m

Key: (D)

Exp: $\vec{E}_{12} = \frac{Q\vec{R}_{12}}{4\pi\varepsilon_0 |\vec{R}_{12}|^3}$

$$\vec{E}_{12} = \frac{1\times10^{-9}(-0.1\hat{a}_z)}{4\pi(8.854\times10^{-12})(0.1)^3} + \frac{(-1\times10^{-9})((0.3)\hat{a}_z)}{4\pi(8.854\times10^{-12})(0.3)^3}$$

$$= \left[\frac{-10^5}{4\pi(8.854)} - \frac{10^5}{4\pi(8.854)9}\right]\hat{a}_z$$

$$= (-898.774 - 99.863)\hat{a}_z \cong -999.09\hat{a}_z \text{ V/m}$$

15. A separately excited dc motor has an armature resistance R_a=0.05 Ω. The field excitation is kept constant. At an armature voltage of 100V, the motor produces a torque of 500Nm at zero speed. Neglecting all mechanical losses, the no-load speed of the motor (in radian/s) for an armature voltage of 150 V is _____ (up to 2 decimal places).

Key: (600)

Exp: Torque

Produced by motor = 500N-m

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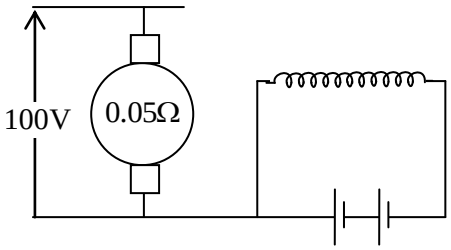
At zero speed, such that



$E_L = K\phi\omega = 0$

$\therefore I = \dfrac{V - E_b}{R_a} = \dfrac{100 - 0}{0.05} = 2000A$

Also, $T = k\phi I_a$

$k\phi = T/I_a = \dfrac{500}{2000} = \dfrac{5}{20} = \dfrac{1}{4}$

For armature voltage of 150V, no load speed in ω_{nL}

At no load $I_{nL} = 0$

$\therefore V = E_b = 150V$

$\therefore E_b = k\phi\omega \left[\because \text{Field excitation or flux is constant, } k\phi = \text{constant}\right]$

$\omega = \dfrac{E_b}{K\phi} = \dfrac{150}{1/4} = 600 \text{ rad/sec}$

16. In a salient pole synchronous motor, the developed reluctance torque attains the maximum value when the load angle in electrical degrees is

(A) 0 (B) 45 (C) 60 (D) 90

Key: (B)

Exp: Reluctance torque $\propto \sin 2\delta$

Torque ix maximum when

$2\delta = 90° \Rightarrow \delta = 45°$

17. Consider a lossy transmission line with V_1 and V_2 as the sending and receiving end voltages, respectively. Z and X are the series impedance and reactance of the line, respectively. Z and X are the series impedance and reactance of the line, respectively. The steady-state stability limit for the transmission line will be

(A) greater than $\left|\dfrac{V_1V_2}{X}\right|$ (B) less than $\left|\dfrac{V_1V_2}{X}\right|$

(C) equal to $\left|\dfrac{V_1V_2}{X}\right|$ (D) equal to $\left|\dfrac{V_1V_2}{Z}\right|$

Key: (B)

Exp: Power with impudence Z,

$P = \dfrac{V_1V_2}{|Z|}\cos(\theta - \delta) - \dfrac{V_2^2}{Z}\cos\theta$

$P_{max_1} = \dfrac{V_1V_2}{|Z|} - \dfrac{V_2^2}{|Z|}\cos(\text{for } \theta = \delta)$

Power with reactence X,

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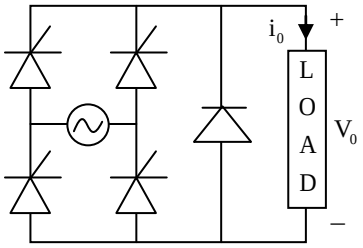
$$P = \frac{V_1 V_2}{X}\sin\delta$$

$$P_{max_2} = \frac{V_1 V_2}{X}\left(\text{for } \delta = 90^\circ\right)$$

i.e $P_{max_2} > P_{max_1}$

$\therefore$ Steady state stability limit for transmission line $< P_{max_2} = \frac{V_1 V_2}{X}$

18. A single phase fully controlled rectifier is supplying a load with an anti-parallel diode as shown in the figure. All switches and diodes are ideal. Which one of the following is true for instantaneous load voltage and current?

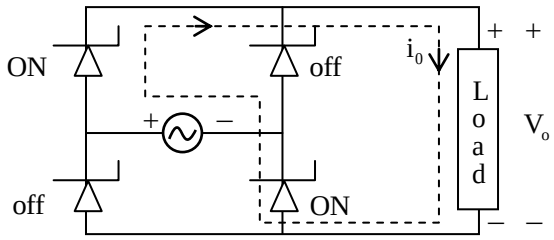


(A) $v_0 \geq 0 \,\&\, i_0 < 0$ (B) $v_0 < 0 \,\&\, i_0 < 0$

(C) $v_0 \geq 0 \,\&\, i_0 \geq 0$ (D) $v_0 < 0 \,\&\, i_0 \geq 0$

Key: (C)

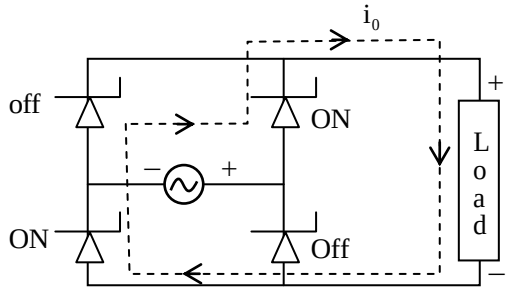
Exp: <u>During forward bias</u>



V_o [Free wheeling diode is off]

Let $V_{in}(t) = \mu_m \sin(\omega t), V_0(t) = \mu_n \sin(\omega t)$[positive]

<u>During reverse bias</u>



[Free wheeling diode is off]

$V_o(t) = V_m \sin(\omega t)$[positive]

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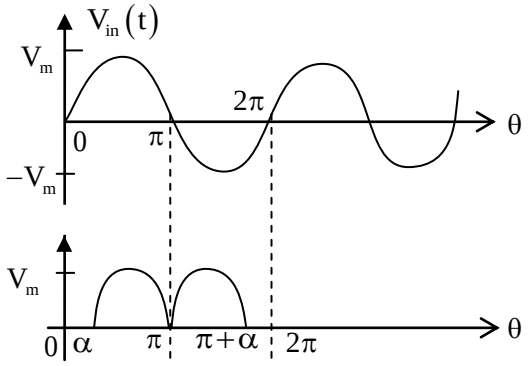


Key concept:

SCR allows current only in one direction, Anode to cathode $i_0 \geq 0$

19. Consider a unity feedback system with forward transfer function given by

$$G(s)=\frac{1}{(s+1)(s+2)}$$

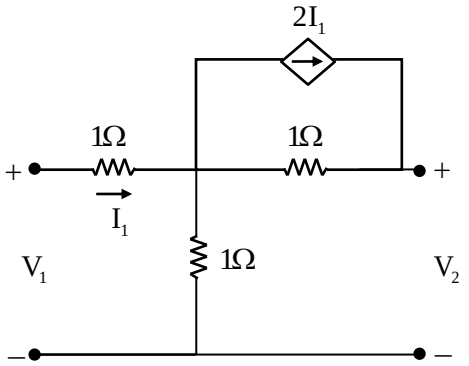
The steady state error in the output of the system for a unit step input is _____ (upto 2 decimal places).

Key: (0.67)

Exp: unit step input, $K_p=\lim_{s\to 0} G(s)=\frac{1}{2}$

for unit step input, $e_{ss}=\frac{A}{1+K_p}=\frac{1}{1+1/2}=2/3=0.67$

20. In the two port network shown, the h_{11} parameter $\left(\text{Where, } h_{11}=\frac{V_1}{I_1}, \text{when } V_2=0\right)$ in ohms is _____ (up to 2 decimal places).



Key: (0.5)

Exp: → when $V_2=0$ the output port is short circuited

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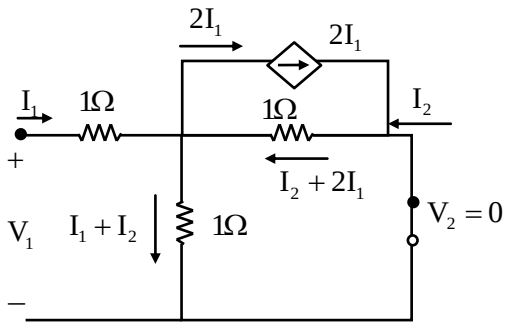


→ Writing KVL on the input loop we have

$$V_1 - 1(I_1) - 1(I_1 + I_2) = 0$$

$$\Rightarrow V_1 = -2I_1 + I_2 \quad ...(1)$$

→ Writing KVL on the output loop we have

$$-1(I_2 + 2I_1) - 1(I_1 + I_2) = 0$$

$$\Rightarrow 2I_2 + 3I_1 = 0$$

$$\Rightarrow I_2 = \frac{-3}{2} I_1 \quad ....(2)$$

→ Using equation 2 in equation 1, we have

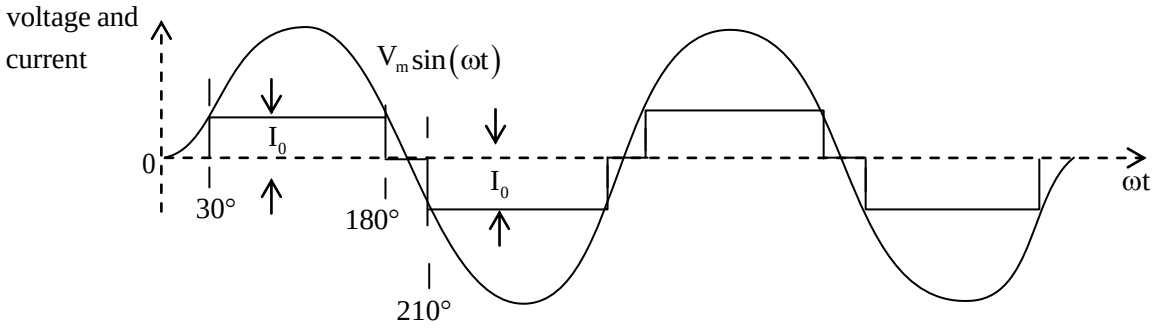
$$V_1 = 2I_1 + \left(\frac{-3}{2}\right) I_1$$

$$V_1 = 0.5 I_1$$

$$\Rightarrow h_{11} = \left.\frac{V_1}{I_1}\right|_{v_2=0} = 0.5$$

$$h_1 = 0.5$$

21. The waveform of the current drawn by a semi-converter from a sinusoidal AC voltage source is shown in the figure. If I_0=20 A, the rms value of fundamental component of the current is _____ A (up 2 decimal places).



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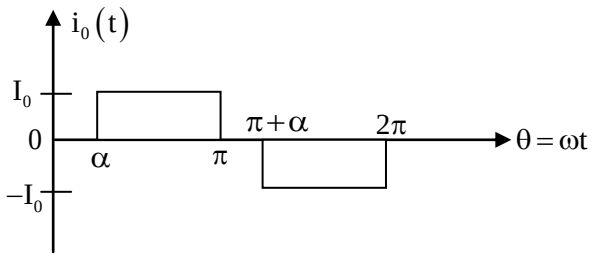
Key: (17.39)

Exp:



Fourier series representation of $i_o(t)$ is

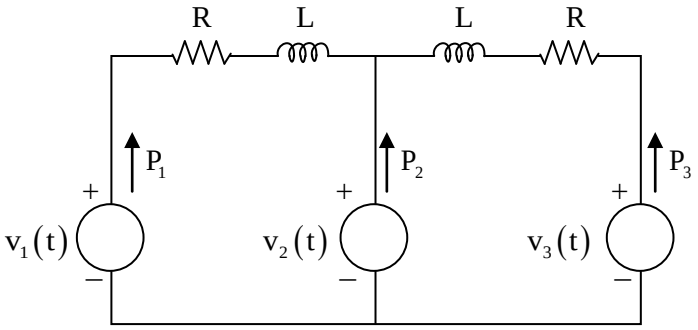
$$i_0(t)=\sum_{n=1,3,5}^{\infty}\left(\frac{4I_0}{n\pi}\right)\cos\left(\frac{n\alpha}{2}\right)\sin\left[n\omega t-\frac{n\alpha}{2}\right]$$

RMS value of nth harmonic is $n=\frac{4I_0}{\sqrt{2}n\pi}\cos\frac{n\alpha}{2}=\frac{2\sqrt{2}}{n\pi}I_0\cos\left(\frac{n\alpha}{2}\right)$

RMS value of fundamental is $I_{S1}=\frac{2\sqrt{2}}{\pi}I_0\cos\frac{\alpha}{2}$

$$=\frac{2\sqrt{2}}{\pi}20\cos\left(\frac{30}{2}\right)=17.39A$$

22. In the figure, the voltages are $v_1(t)=100\cos(\omega t)$, $v_2(t)=100\cos(\omega t+\pi/18)$ and $v_3(t)=100\cos(\omega t+\pi/36)$. The circuit is in sinusoidal steady state, and R << ωL. P_1, P_2 and P_3 are the average power outputs. Which one of the following statements is true?



(A) $P_1 = P_2 = P_3 = 0$

(B) $P_1 < 0, P_2 > 0, P_3 > 0$

(C) $P_1 < 0, P_2 > 0, P_3 < 0$

(D) $P_1 > 0, P_2 < 0, P_3 > 0$

Key: (C)

Exp: $V_1(t)=100\cos(\omega t)$

$$V_2(t)=100\cos\left(\omega t+\frac{\pi}{18}\right)$$

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$$V_3(t) = 100\cos\left(\omega t + \frac{\pi}{36}\right)$$

$$|V_1(t)| = |V_2(t)| = |V_3(t)| = 100$$

$$\underline{|V_1(t)} = 0°$$

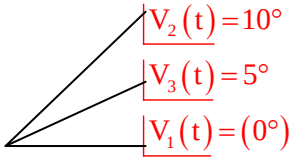
$$\underline{|V_2(t)} = \frac{\pi}{18} = \frac{180}{18} = 10°$$

$$\underline{|V_3(t)} = \frac{\pi}{36} = 5°$$

$V_2(t)$ is leading $V_3(t)$ and $V_1(t)$ by $10°$ and $5°$.

$\therefore$ $V_2(t)$ is source & delivering power $(P_2 > 0)$

$V_1(t)$ and $V_3(t)$ are sinks & absorbing power $(P_3 > 0), (P_1 > 0)$



23. Consider a non singular 2×2 square matrix A. If trace (A) = 4 and trace (A^2) = 5, the determinant of the matrix A is _____ (up to 1 decimal place).

Key: (5.5)

Exp: Let $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \Rightarrow$ Trace of $A = a + d$

$$\& A^2 = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} a & b \\ c & d \end{bmatrix} = \begin{bmatrix} a^2 + bc & ab + bd \\ ac + cd & bc + d^2 \end{bmatrix}$$

$$\Rightarrow \text{Trace of } A^2 = a^2 + bc + bc + d^2$$

$$= a^2 + 2bc + d^2$$

Given $a + d = 4$ ...(1) &

$a^2 + 2bc + d^2 = 5$ ...(2)

$$(1)^2 \Rightarrow (a+d)^2 = 16 \Rightarrow a^2 + d^2 + 2ad = 16$$

$$\Rightarrow 5 - 2bc + 2ad = 16 \left(\because \text{from}(2)\right)$$

$$\Rightarrow 2(ad - bc) = 11$$

$$\Rightarrow ad - bc = \frac{11}{2} = 5.5$$

24. The series impedance matrix of a short three phase transmission line in phase coordinates is $\begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix}$. If the positive sequence impedance is $(1+j10)\,\Omega$, and the zero sequence is $(4+j31)\,\Omega$.

Then the imaginary part of Z_m (in Ω) is _____ (up to 2 decimal places).

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Key: (7)

Exp: $Z_1 = Z_s - Z_m = 1 + j10 \quad ....(1)$

$Z_0 = Z_s + 2Z_m = 4 + j31 \quad ....(2)$

$(2) - (1)$

$Z_0 - Z_1 = 3Z_m = 3 + j21$

$Z_m = 1 + j7$

$\text{Im}(Z_m) = 7\Omega$

25. The positive, negative and zero sequence impedances of a 125 MVA, three phase, 15.5kV, star-grounded, 50Hz generator are j0.1 pu, j0.05 pu and j0.01 pu respectively on the machine rating base. The machine is unloaded and working at the rated terminal voltage. If the grounding impedance of the generator is j0.01 pu, then the magnitude of fault current for a b-phase to ground fault (in kA) is _____ (up to 2 decimal places).

Key: (73.51)

Exp: $I_f(pu) = \dfrac{3}{Z_1 + Z_2 + Z_0 + 3Z_n}$

$= \dfrac{3}{j0.1 + j0.05 + j0.01 + (3 \times 0.01)} = \dfrac{3}{0.19}$

$I_f(\text{actual}) = (I_f)_{pu} \times (I_b)_{base}$

$= \left(\dfrac{3}{0.19} \times \dfrac{S_b^{\nearrow \text{MVA}}}{\sqrt{3} V_b^{\searrow \text{KV}}} \right) \text{kA}$

$= \dfrac{3}{0.19} \times \dfrac{125}{\sqrt{3} \times 15.5} = 73.51\text{kA}$

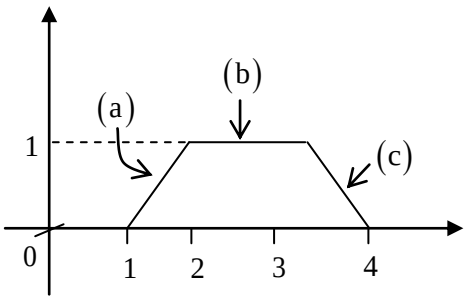
26. The signal energy of the continuous time signal

$x(t) = [(t-1)u(t-1)] - [(t-2)u(t-2)] - [(t-3)u(t-3)] + [(t-4)u(t-4)]$ is

(A) 11/3 (B) 7/3 (C) 1/3 (D) 5/3

Key: (D)

Exp: $x(t) = \left[(t-1)u(t-1)\right] - \left[(t-2)u(t-2)\right] - \left[(t-3)u(t-3)\right] + \left[(t-4)u(t-4)\right]$



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$$\text{Energy of } x(t) = \int_1^2 (a)^2\,dt + \int_2^3 (b)^2\,dt + \int_3^4 (c)^2.dt$$

$$\int_1^2 (a)^2\,dt = \int_3^4 (c)^2\,dt$$

$$\Rightarrow \text{Energy of } x(t) = 2\int_1^2 (a)^2\,dt + \int_2^3 (b)^2\,dt$$

$$= 2\int_1^2 (t-1)^2\,dt + \int_2^3 1^2\,dt$$

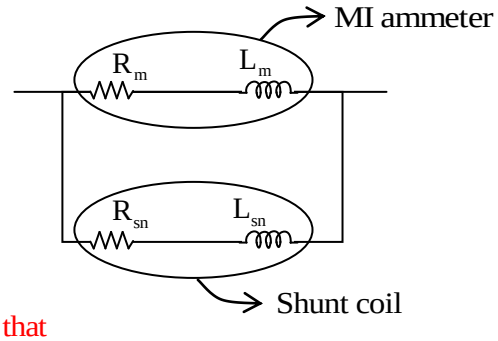
$$= 2\times\frac{(t-1)^3}{3}\Big|_1^2 + 1 = 5/3.$$

27. A 0-1 Ampere moving iron ammeter has an internal resistance of 50 $m\Omega$ and inductance of 0.1mH. A shunt coil is connected to extend its range to 0-10 Ampere for all operating frequencies. The time constant in milliseconds and resistance in $m\Omega$ of the shunt coil respectively are

(A) 2, 5.55 (C) 2,1 (C) 2.18,0.55 (D) 11.1,2

Key: (A)

Exp:



→ It is given that

$R_m = 50m\Omega$

$L_m = 0.1\,mH$

$\text{Existing range} = 0-1\,\text{ampere}$

$\text{Reauired range} = 0-10\,\text{ampere}$

$$\text{Scaling factor}\,(m) = \frac{\text{Required}}{\text{Existing}} = \frac{10}{1} = 10$$

→ The required value shunt coil resistance is given by

$$R_{sn} = \frac{R_m}{m-1} = \frac{50\times10^{-3}}{10-1} = 5.55m\Omega.$$

→ To make the meter independent of frequency, the time constant of both parallel branch should be same i.e.

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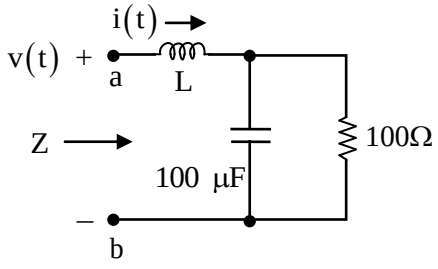
$$\frac{L_{sn}}{R_{sn}} = \frac{L_m}{R_m}$$

$$\Rightarrow \tau_{sn} = \frac{0.1\times10^{-3}}{50\times10^{-3}} = 0.002 = 2\text{m.sec}$$

$$\rightarrow \tau_{sn} = 2\text{ m.sec}$$

$$R_{sn} = 5.55\text{ mA.}$$

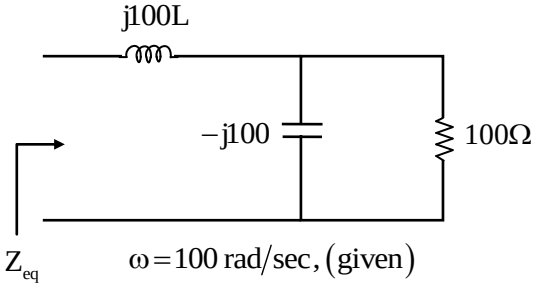
28. The voltage v(t) across the terminals a and b as shown in the figure, is a sinusoidal voltage having a frequency ω=100 radian/s. When the inductor current i(t) is in phase with the voltage v(t), the magnitude of the impedance Z (in Ω) seen between the terminals a and b is _____ (up to 2 decimal places).



Key: (50)

Exp: $\rightarrow$ when the Source voltage and current are in phase, then the circuit is under resonance and the impedance is purely real.

$\rightarrow$Transforming the given network into its equivalent phasor domain we have



at $\omega = 100$

$$Z_L = j\omega L = j100L$$

$$Z_C = \frac{-j}{\omega C} = -j100$$

$$Z_R = 100\Omega$$

$$\rightarrow Z_{eq} = [j100L] + [100 \,||\, (-j100)]$$

$$= [j100L] + \left[\frac{-j10^4}{100 - j100}\right]$$

$$= [j100L] + \frac{-j(10^4)(100 + j100)}{(100 - j100)(100 + j100)}$$

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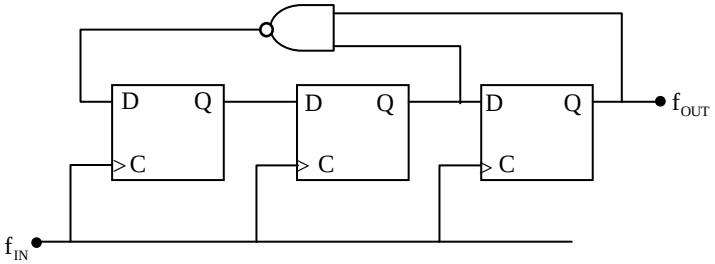
$$= \left[\frac{10^6}{100^2+100^2}\right] + j\left[100L - \frac{10^6}{100^2+100^2}\right]$$

$\rightarrow$Since the circuit is under resonance, the imaginary part of $Z_{eq} = 0$, hence

$$Z_{eq} = \frac{10^6}{100^2+100^2}$$

$$= \frac{10^6}{2\times 100^2} \Rightarrow \frac{10^6}{2\times 10^4} = \frac{10^2}{2} = 50\Omega$$

29. Which one of the following statements is true about the digital circuit shown in the figure?



(A) It can be used for dividing the input frequency by 3.

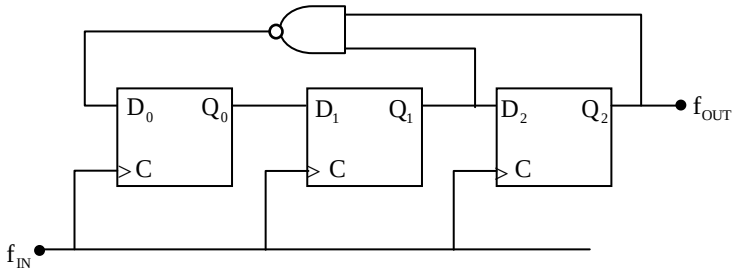
(B) It can be used for dividing the input frequency by 5.

(C) It can be used for dividing the input frequency by 7.

(D) It cannot be reliably used as a frequency divider due to disjoint internal cycles.

Key: (B)

Exp:



$D_0 = \overline{Q_1\ Q_2}$

Clk	$\overline{Q_1Q_2}$ (D_0)	Q_0 (D_1)	Q_1 (D_2)	Q_0	Q_1	Q_2
				0	0	0
1	1	0	0	1	0	0
2	1	1	0	1	1	0
3	1	1	1	1	1	1
4	0	1	1	0	1	1
5	0	0	1	0	0	1
6	1	0	0	1	0	0

Repeated

i.e., MOD 5

Hence, $f_o = \frac{f_i}{5}$

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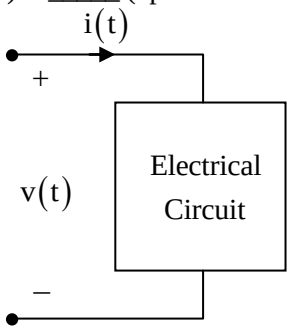
30. The voltage across the circuit in the figure. And the current through it, are given by the following expressions:

$v(t) = 5 - 10\cos(\omega t + 60°)\,V$

$i(t) = 5 + X\cos(\omega t)\,A$

Where $\omega = 100\pi$ radian/s. If the average power delivered to the circuit is zero, then the value of X (in Ampere) is _____ (up to 2 decimal places).



Key: (10)

Exp: $\rightarrow$If the voltage and currents of electrical circuit is in the form of

$V(t) = V_0 + V_1\cos(\omega_1 t + \phi_{v_1}) + V_2\cos(\omega_2 t + \phi_{v_2}) + ...$

$i(t) = i_0 + i_1\cos(\omega_1 t + \phi_{i_1}) + i_2\cos(\omega_2 t + \phi_{i_2}) + ...$

Then the average power is given by

$P_{avg} = \frac{1}{T}\int_0^T V(t)i(t)dt,$

$= V_0 i_0 + \frac{V_1}{\sqrt{2}}\frac{i_1}{\sqrt{2}}\cos\left[\phi_{v_1} - \phi_{i_1}\right] + \frac{V_2}{\sqrt{2}}\frac{I_2}{\sqrt{2}}\cos(\phi_{v_2} - \phi_{i_2}) + ...$

(its a very well known standard result)

$\rightarrow$ It is given that

$V(t) = 5 - 10\cos(\omega t + 60°)$

$= 5 + 10\cos(\omega t - 120°)$

$i(t) = 5 + x\cos(\omega t + 0°)$

then $P_{avg} = [5\times 5] + \left[\left(\frac{10}{\sqrt{2}}\right)\left(\frac{x}{\sqrt{2}}\right)\cos(-120° - 0°,)\right]$

$\Rightarrow 0 = 25 + \left[\left(\frac{10x}{2}\right)\cos(-120°)\right] (\because P_{avg} = 0, \text{given})$

$\Rightarrow 0 = 25 + \left[(5x)(-1/2)\right]$

$\Rightarrow \frac{5}{2}x = 25$

$\Rightarrow x = 10$

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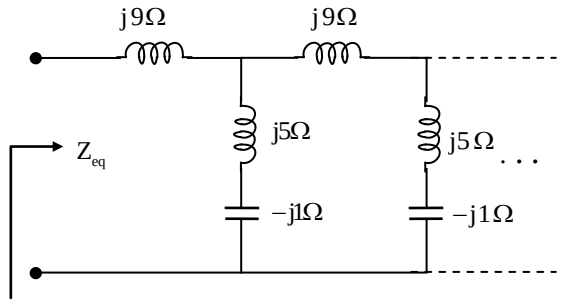
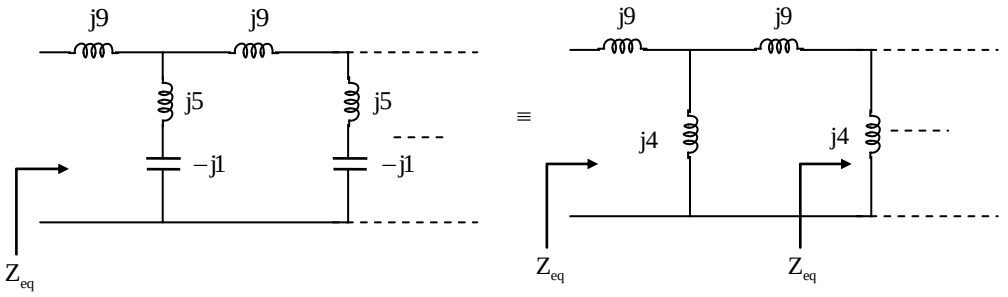
31. The equivalent impedance Z_{eq} for the infinite ladder circuit shown in the figure is



(A) $j12\,\Omega$ (B) $-j12\,\Omega$ (C) $j13\,\Omega$ (D) $13\,\Omega$

Key: (A)

Exp:



$$Z_{eq} = j9 + \left[j4 \,||\, Z_{eq} \right]$$

$$= j9 + \left[\frac{(j4)(Z_{eq})}{j4 + Z_{eq}} \right]$$

$$\Rightarrow \left[j4 + Z_{eq} \right] Z_{eq} = \left[(j9)(j4 + Z_{eq}) \right] + \left[(j4)(Z_{eq}) \right]$$

$$\Rightarrow (j4)(Z_{eq}) + Z_{eq}^{\,2} = -36 + j9Z_{eq} + (j4)(Z_{eq})$$

$$\Rightarrow Z_{eq}^{\,2} - (j9) Z_{eq} + 36 = 0$$

$$\Rightarrow Z_{eq} = \frac{-(-j9) \pm \sqrt{(-j9)^2 (4 \times 36 \times 1)}}{(2 \times 1)}$$

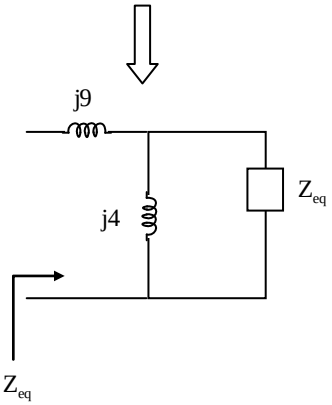
$$= \frac{j9 \pm \sqrt{-81 - 144}}{2}$$

$$= \frac{j9 \pm \sqrt{-225}}{2}$$

$$= \frac{j9 \pm j15}{2}$$

$$= \frac{j9 + j15}{2} \text{ or } \frac{jq - j15}{2}$$

$$= j12 \text{ or } -j3$$



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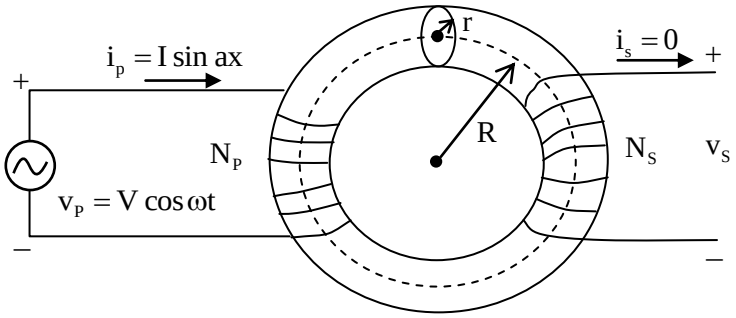
→ Since the nature of the network is overally inductive the reactance must should be positive (for capacitive case the reactance could have –ve).

Hence we are discarding –j3.

→ $Z_{eq} = j12$

32. A transformer with toroidal core of permeability μ is shown in the figure. Assuming uniform flux density across the circular core cross-section of radius r < < R, and neglecting any leakage flux, the best estimate for the mean radius R is



(A) $\frac{\mu V r^2 N_p^2 \omega}{I}$ (B) $\frac{\mu I r^2 N_p V_s \omega}{V}$ (C) $\frac{\mu V r^2 N_p^2 \omega}{2I}$ (D) $\frac{\mu I r^2 N_p^2 \omega}{2V}$

Key: (D)

Exp: The inductance of primary is $L = \frac{Np^2}{S}$

Where S is reluctance of magnetic path

$$S = \frac{\ell}{\mu A} = \frac{2\pi R}{\mu\left[\pi r^2\right]} = \frac{2R}{\mu r^2}$$

$$\therefore L = \frac{Np^2}{\frac{2R}{\mu r^2}} = \frac{Np^2 \mu r^2}{2R}$$

$$X_L = \omega L = \frac{\omega Np^2 \mu r^2}{2R}$$

$$V = IX_L = \frac{I.\omega.Np^2.\mu r^2}{2R}$$

$$R = \frac{\mu.I.r^2.Np^2.\omega}{2V}$$

33. The number of roots of the polynomial, $s^7 + s^6 + 7s^5 + 14s^4 + 31s^3 + 73s^2 + 25s + 200$ in the open left half of the complex plane is

(A) 3 (B) 4 (C) 5 (D) 6

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Key: (A)

Exp:

s^7		1	7	31	25
s^6	2	1	14	73	200
s^5	sign	−7	−42	−175	
s^4	change	+8	+48	+200	
s^3		1	3	0	
s^2		24	200		
s^1	2	−128	0		
s^0	sign change	200			

$A(s) = 8s^4 + 48s^2 + 200$

$\frac{dA(s)}{ds} = 32s^3 + 96s$

No. of sign changes = 4

Right hand roots = 4

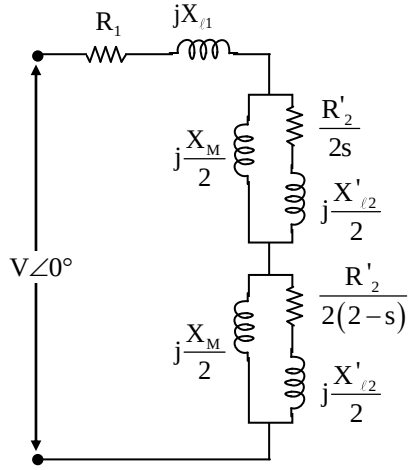
No. of imaginary roots = order of auxillary eqn $- 2$(No.of sign changes below zero th row)

$= 4 - 2(2) = 0$

$\therefore$ left hand roots

$= 7 - 4 = 3$

34. The equivalent circuit of a single phase induction motor is shown in the figure, where the parameters are $R_1 = R_2 = X_{\ell 1} + X_{\ell 2} = 12\Omega, X_M = 240\Omega$ and s is the slip. At no load, the motor speed can be approximated to be the synchronous speed. The no-load lagging power factor of the motor is ____ (up to 3 decimal places).



Key: (0.106)

Exp: At no load, $\omega_m \approx \omega_s$. $\therefore S = 0. \therefore \frac{R_2'}{2S} \approx \infty$

The modified equivalent Circuit is

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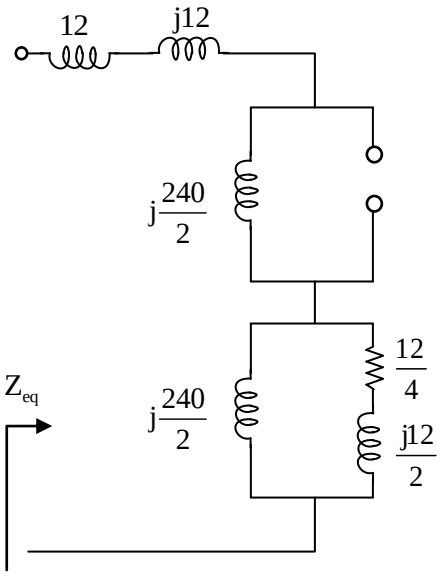

$$\frac{R_2'}{2(2-s)} = \frac{R_2'}{4}$$

$$Z_{eq} = 12 + j12 + j120 + \frac{j120 \times (3 + j6)}{(3 + j6 + j120)}$$

$$= 12 + j132 + \left[\frac{j120 \times (3 + j6)}{3 + j126}\right]$$

$$= 14.72 + j137.78$$

$$= 138.561\boxed{83.9}$$

No load p.f $\cos\phi = \cos 83.9 = 0.106$ lag.

35. A 3-phase 900kVA, 3kV/$\sqrt{3}$ kV (Δ / Y), 50 Hz transformer has primary (high voltage side) resistance per phase of 0.3Ω and secondary (low voltage side) resistance per phase of 0.02Ω, Iron loss of the transformer is 10kW. The full load % efficiency of the transformer operated at unity power factor is _____ (up to 2 decimal places).

Key: (97.36)

Exp: $a_{ph} = \frac{3}{\sqrt{3}/\sqrt{3}} = 3;$

$$I_{Hv} = I_1 = \frac{900}{3 \times 3} = 100A$$

$$R_{1eq} = R_1 + a^2 R_2$$

$$= 0.3 + 9 \times (0.02) = 0.48\Omega$$

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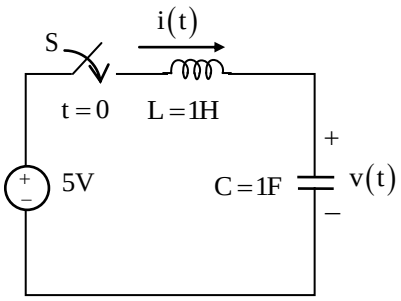
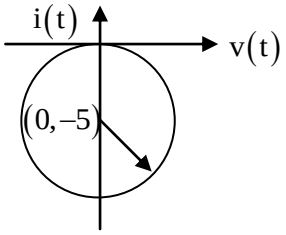
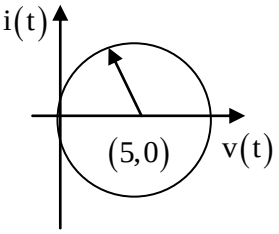
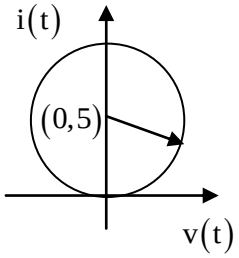
$$\text{Cu loss}(3-\phi) = 3I_1^2 R_{1eq}$$
$$= 3\times 100^2 \times 0.48$$
$$= 14400\text{W} = 14.4\text{kW}$$
$$\text{Core loss} = 10\text{kW}$$
$$\%\eta = \frac{900}{900+10+14.4} = 97.36\%$$

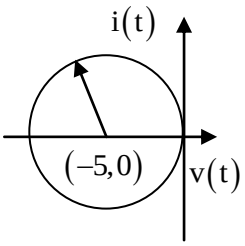
36. A DC voltage source is connected to a series L-C circuit by turning on the switch S at time t=0 as shown in the figure. Assume i(0)=0, v(0)=0. Which one of the following circular loci represents the plot of i(t) versus v(t)?



(A)


(B)


(C)


(D)


Key: (B)

Exp: → Since the network is of 2nd order, to obtain the expression of v(t)and i(t) we should use Laplace transform approach.

→ Once we get the expression for v(t) and i(t) we can plot the loci by observing them at different time instant.

→ Transforming the given time domain network into its equivalent s-domain form for t>0, we have

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$$\rightarrow I(s)=\frac{5/s}{s+1/s}=\frac{5}{s^2+1}$$

$$\Rightarrow i(t)=5\sin t$$

$$\rightarrow V(s)=\left[\frac{1/s}{s+1/5}\right][5/s]$$

$$=\frac{5}{s(s^2+1)}$$

$$=\left[\frac{5}{s}\right]+\left[\frac{-2.5}{s+j1}+\frac{-2.5}{s-j1}\right]$$

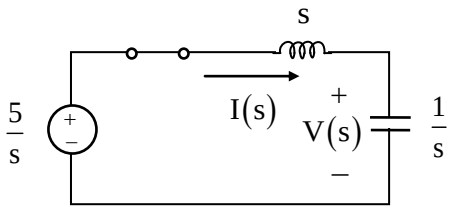
$$=\left[\frac{5}{s}\right]-\left[\frac{5s}{s^2+1}\right]$$

$$\Rightarrow v(t)=5-5\cos$$

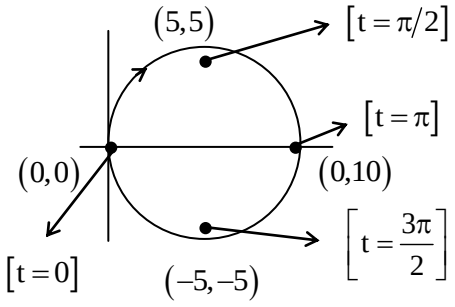
$\rightarrow$ Finaly we have

$i(t)=5\sin t$

$v(t)=5-5\cos t$



t	$i(t)$	$v(t)$	Coordinate
0	0	0	$\rightarrow 0,0$
$\frac{\pi}{2}$	5	5	$\rightarrow 5,5$
π	0	10	$\rightarrow 0,10$
$\frac{3\pi}{2}$	-5	-5	$\rightarrow -5,5$
2π	0	0	$\rightarrow 0,0$



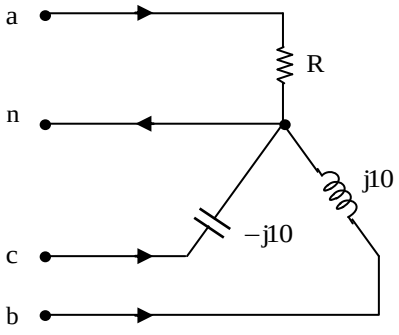
37. A three phase load is connected to a three phase balanced supply as shown in the figure.

If

$V_{an}=100\angle 0°V$, $V_{bn}=100\angle -120°V$ and $V_{cn}=100\angle -240°V$

(angles are considered positive in the anti clock wise direction).

The value of R for zero current in the neutral wire is _____ Ω (up to 2 decimal places).



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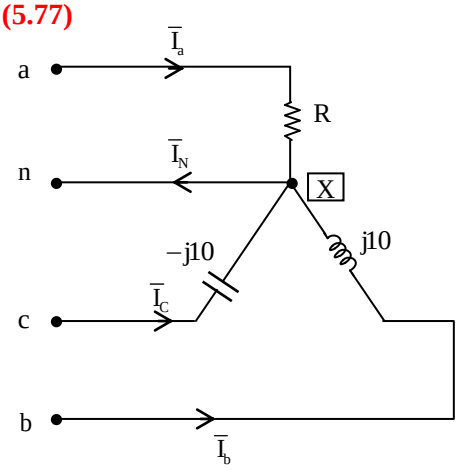
Key: (5.77)

Exp:



By KCL at node x, we have

$$\bar{I}_a + \bar{I}_b + \bar{I}_c = \bar{I}_N$$

$$\Rightarrow \frac{\overline{V_{an}}}{R} + \frac{\overline{V_{bn}}}{j10} + \frac{\overline{V_{cn}}}{-j10} = \bar{I}_N$$

$$\Rightarrow \frac{100\angle 0°}{R} + \frac{100\angle -120°}{10\angle 90°} + \frac{100\angle -240°}{10\angle -90°} = 0 \left(\because \bar{I}_N = 0 \text{ given}\right)$$

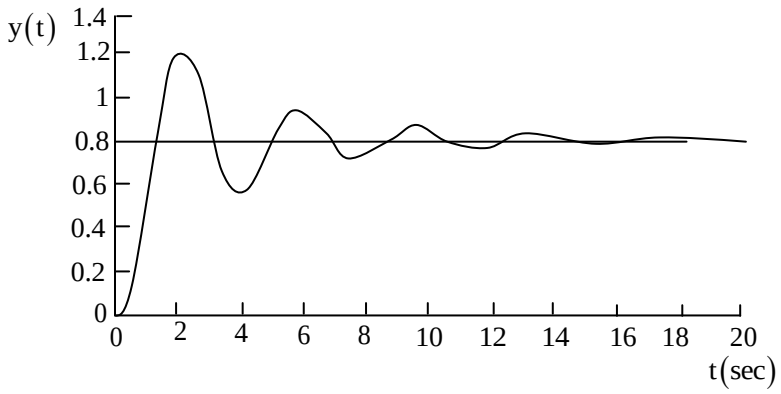
$$\Rightarrow \frac{100}{R} + 10\angle -210° + 10\angle -150° = 0$$

$$\Rightarrow \frac{100}{R} = -\left[10\angle -210° + 10\angle -150°\right]$$

$$\Rightarrow R = \frac{-100}{\left[10\angle -210°\right] + \left[10\angle -150°\right]}$$

$$\Rightarrow R = 5.77\Omega$$

38. The unit step response y(t) of a unity feedback system with open loop transfer function G(s) H(s) $= \frac{K}{(s+1)^2(s+2)}$ is shown in the figure. The value of K is _____ (up to 2 decimal places).



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Key: (8)

Exp: Steady state output =0.8

Input is unit step input =1

Stead state error e_{ss} = 0.2

For unit step input $K_p = \lim_{s\to 0} G(s)H(s)$

$$= \lim_{s\to 0} \frac{K}{(s+1)^2(s+2)} = K/2$$

$$e_{ss} = \frac{A}{1+K_p}$$

$$0.2 = \frac{1}{1+K/2}$$

$$1+K/2 = 5 \Rightarrow K/2 = 4;\ K = 8$$

39. The Fourier transform of a continuous- time signal x(t) is given by $X(\omega) = \frac{1}{(10+j\omega)}, -\infty < \omega < \infty.$ where $j = \sqrt{-1}$ and ω denotes frequency. Then the value of $|\ell n x(t)|$ at $t = 1$ _____(up to 1 decimal place.) (ln denotes the logarithm to base e).

Key: (10)

Exp: Given $X(\omega) = \frac{1}{(10+j\omega)^2}$,

Converting to s domain, $X(s) = \frac{1}{(s+10)^2}$

we know $e^{-10t}u(t) \longleftrightarrow \frac{1}{s+10}$

$$t.e^{-10t} \longleftrightarrow \frac{1}{(s+10)^2}$$

$$\Rightarrow x(t) = t.e^{-10t}u(t)$$

$$\Rightarrow |\ell n\ x(t)| = |\ell n\ t.e^{-10t}u(t)|$$

$$= |\ell n\ t + (-10t\ \ell n\ c)|$$

$$= |\ell n\ 1 - 10\times 1\times 1| = |-10| = 10.0$$

40. Consider a system governed by the following equations

$$\frac{dx_1(t)}{dt} = x_2(t) - x_1(t)$$

$$\frac{dx_2(t)}{dt} = x_1(t) - x_2(t)$$

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The initial conditions are such that $x_1(0) < x_2(0) < \infty$. Let $x_{1f} = \lim_{t\to\infty} x_1(t)$ and $x_{2f} = \lim_{t\to\infty} x_2(t)$. Which one of the following is true?

(A) $x_{1f} < x_{2f} < \infty$ (B) $x_{2f} < x_{1f} < \infty$

(C) $x_{1f} = x_{2f} < \infty$ (D) $x_{1f} = x_{2f} = \infty$

Key: (C)

Exp: $\frac{dx_1(t)}{dt} = x_2(t) - x_1(t) \ldots (1)$

$\frac{dx_2(t)}{dt} = x_1(t) - x_2(t) \ldots (2)$

Differentiating (1) w.r.t 't'

$\Rightarrow \frac{d^2x_1(t)}{dt^2} = \frac{dx_2(t)}{dt} - \frac{dx_1(t)}{dt}$

$= x_1(t) - x_2(t) - \frac{dx_1(t)}{dt} (\because \text{from } (2))$

$= x_1(t) - \left(\frac{dx_1(t)}{dt} + x_1(t)\right) - \frac{dx_1(t)}{dt} (\because \text{from } (1))$

$\Rightarrow \frac{d^2x_1(t)}{dt^2} + 2\frac{dx_1(t)}{dt} = 0$

$D^2 + 2D = 0$

$D(D+2) = 0$

$\Rightarrow D = 0, -2$

Solution, $x_1(t) = C_1 + C_2 e^{-2t}$

$x_{1f} = \lim_{t\to\infty} x_1(t) = C_1$

Similarly, Differently (2) w.r.t 't' using (1) & (2)

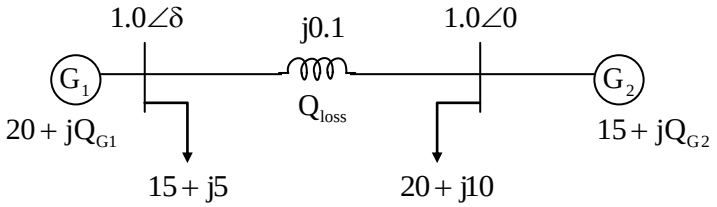
we get $\frac{d^2x_2(t)}{dt^2} + \frac{2dx_2(t)}{dt} = 0$

$\therefore$ solution, $x_2(t) = C_1 + C_2 e^{-2t}$

$x_{2f} = \lim_{t\to\infty} x_2(t) = C_1$

$\Rightarrow x_{1f} = x_{2f} < \infty$

41. Consider the two bus power system network with given loads as shown in the figure.



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All the values shown in the figure are in per unit. The reactive power supplied by generator G_1 and G_2 are Q_{G1} and Q_{G2} respectively. The per unit values of Q_{G1}, Q_{G2}, and line reactive power loss (Q_{loss}) respectively are

(A) 5.00, 12.68, 2.68
(B) 6.34, 10.00, 1.34
(C) 6.34, 11.34, 2.68
(D) 5.00, 11.34, 1.34

Key: (C)

Exp: $P = \frac{V_S V_R}{x} \sin\delta$

$5 = \frac{1\times 1}{0.1}\sin\delta$

$\sin\delta = 0.5$

$\delta = 30°$

$Q_s = \frac{|V_S|}{X}\left(|V_S| - |V_R|\cos\delta\right) = \frac{1}{0.1}\left(1 - \cos 30°\right) = 1.34\,pu$

$Q_R = \frac{|V_R|}{x}\left(|V_S|\cos\delta - |V_R|\right) = \frac{1}{0.1}\left(\cos 30° - 1\right) = -1.34pu$

$Q_{loss} = Q_S - Q_R$

$= 1.34 - (-1.34) = 2.68\,pu$

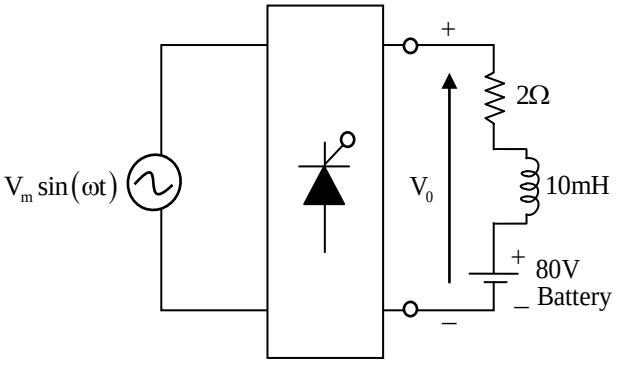
$Q_{G1} = Q_{load} + Q_S$

$= 5 + 1.34 = 6.34pu$

$Q_{G2} + Q_R = Q_{load}$

$Q_{G2} = -Q_R + Q_{load} = 1.34 + 10 = 11.34pu$

42. A phase controlled single phase rectifier, supplied by an AC source, feeds power to an R-L-E load as shown in the figure. The rectifier output voltage has an average value given by $V_0 = \frac{V_m}{2\pi}(3 + \cos\alpha)$, where $V_m = 80\pi$ volts and α is the firing angle. If the power delivered to the lossless battery is 1600W, α in degree is _____ (up to 2 decimal places).



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Key: (90)

Exp: Power delivered to lossless battery $= EI_0 = 1600W$

$80\, I_0 = 1600$

$I_0 = 20A$

From given $1-\phi$ rectifier, $V_0 = E + I_0 R$

$$\frac{V_m}{2\pi}\left[3+\cos\alpha\right] = E + I_0 R$$

$$\frac{80\pi}{2\pi}\left[3+\cos\alpha\right] = 80 + 20.2$$

$$40\left[3+\cos\alpha\right] = 120$$

$$3+\cos\alpha = 3$$

$$\cos\alpha = 0$$

$$\alpha = 90°$$

43. The positive, negative and zero sequence impedances of a three phase generator are Z_1, Z_2 and Z_0 respectively. For a line to line fault with fault impedance Z_f, the fault current is $I_{f1} = kI_f$, where I_f is the fault current with zero fault impedance. The relation between Z_f and k is

(A) $Z_f = \dfrac{(Z_1+Z_2)(1-k)}{k}$

(B) $Z_f = \dfrac{(Z_1+Z_2)(1+k)}{k}$

(C) $Z_f = \dfrac{(Z_1+Z_2)k}{1-k}$

(D) $Z_f = \dfrac{(Z_1+Z_2)k}{1+k}$

Key: (A)

Exp: $I_f\,(L-L\text{ fault}) = \dfrac{\sqrt{3}}{Z_1+Z_2}$

$I_{f_1}\,(L-L\text{ fault})$

with fault impedance, $Z_f = \dfrac{\sqrt{3}}{Z_1+Z_2+Z_f}$

$I_{f1} = kI_f\,(\text{given})$

$$\therefore \frac{\sqrt{3}}{Z_1+Z_2+Z_f} = \frac{3\sqrt{3}}{Z_1+Z_2}$$

$$(Z_1+Z_2)k + Z_f k = Z_1 + Z_2$$

$$Z_f k = (Z_1+Z_2)(1-k)$$

$$Z_f = \frac{(Z_1+Z_2)(1-k)}{k}$$

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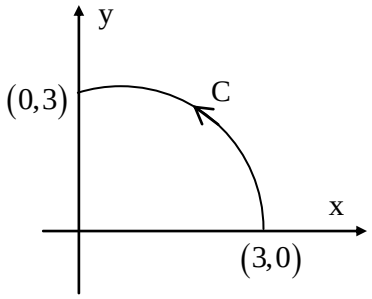
44. As shown in the figure, C is the arc from the point (3, 0) to the point (0, 3) and the circle $x^2+ y^2=9$. The value of the integral $\int_C (y^2+2yx)dx+(2xy+x^2)dy$ is _____ (up to 2 decimal places).



Key: (0)

Exp: Given $x^2+y^2=9$

$\Rightarrow y^2=9-x^2$

$\Rightarrow y=\sqrt{9-x^2}$

$\Rightarrow dy=\frac{1}{2\sqrt{9-x^2}}(-2xdx)=\frac{-x}{\sqrt{9-x^2}}dx$

$\therefore \int_C (y^2+2yx)dx+(2xy+x^2)dy=\int_{x=3}^{0}\left(9-x^2+2x\sqrt{9-x^2}\right)dx+\left(2x\sqrt{9-x^2}+x^2\right)\frac{-xdx}{\sqrt{9-x^2}}$

$=\left[9x-\frac{x^3}{3}-\frac{\left(9-x^2\right)^{\frac{1}{2}+1}}{\frac{1}{2}+1}-2\frac{x^3}{3}\right]_3^0-\int_3^0\frac{x^3}{\sqrt{9-x^2}}dx \quad ...(1)$

Consider, $\int_3^0\frac{x^3}{\sqrt{9-x^2}}dx$, put $\boxed{9-x^2=t} \Rightarrow \int_{t=0}^{a}\frac{9-t}{\sqrt{t}}\left(-\frac{dt}{2}\right)=-18$

from $(1), -18-(-18)=0$

45. Digital input signals A,B,C with A as the MSB and C as the LSB are used to realize the Boolean function $F = m_0 + m_2 + m_3 + m_5 + m_7$, where m_i denotes the i^{th} minterm. In addition, F has a don't care for m_1. The simplified expression for F is given by

(A) $\bar{A}\bar{C}+\bar{B}C+AC$ (B) $\bar{A}+C$

(C) $\bar{C}+A$ (D) $\bar{A}C+BC+A\bar{C}$

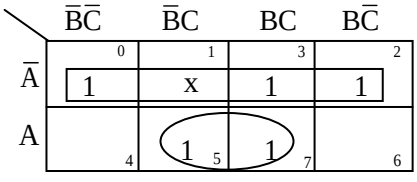
Key: (B)

Exp: $F=\Sigma m(0,2,3,5,7)+d(1)$

$\bar{A}+AC$

$=(\bar{A}+A)(\bar{A}+C)$[Distributive law]

$=\bar{A}+C$



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46. Let $f(x)=3x^3-7x^2+5x+6$. The maximum value of f(x) over the interval [0,2] is _____ (up to 1 decimal place).

Key: (12)

Exp: $f(x)=3x^3-7x^2+5x+6$

$\Rightarrow f'(x)=9x^2-14x+5=0$

$\Rightarrow x=1,5/9$

$f''(x)=18x-14$

$f''(1)>0$ &

$f''(5/9)<0$

$\therefore$ At $x=5/9$, $f(x)$ has local maximum &

$f\left(\frac{5}{9}\right)=\frac{1733}{243}=7.13$

$f(0)=6$

$f(2)=12$

$\therefore$ The maximum value of $f(x)$ in $[0,2]$ is "12"

47. The per unit power output of salient-pole generator which is connected to an infinite bus, is given by the expression, $P=1.4\sin\delta+0.15\sin 2\delta$, where δ is the load angle. Newton Raphson method is used to calculate the value of δ for P=0.8pu. If the initial guess is 30°, then its value (in degree) at the end of the first iteration is

(A) 15° (B) 28.48° (C) 28.74° (D) 31.20°

Key: (C)

Exp: $P=0.8=1.4\sin\delta+0.15\sin 2\delta$

$f(\delta)=1.4\sin\delta+0.15\sin 2\delta-0.8$

By, Newton Raphson method

$\delta_1=\delta_0-\frac{f(\delta_0)}{f'(\delta_0)}$

$=\pi/6-\frac{1.4\sin 30+0.15\sin 60-0.8}{1.4\cos 30°+(2\times 0.15)\cos 60}$

$=0.50164$ rad

$\delta_1=28.74°$

48. Consider the two continuous time signals defined below:

$$x_1(t)=\begin{cases}|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases},\quad x_2(t)=\begin{cases}1-|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases}$$

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These signals are sampled with a sampling period of T=0.25 seconds to obtain discrete time signals $x_1[n]$ and $x_2[n]$, respectively. Which one of the following statements is true?

(A) The energy of $x_1[n]$ is greater than the energy of $x_2[n]$.

(B) The energy of $x_2[n]$ is greater than the energy of $x_1[n]$.

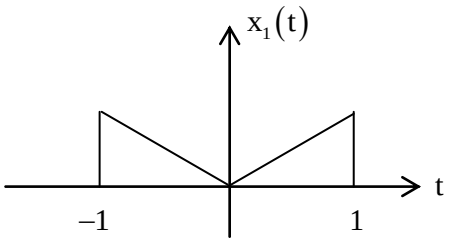
(C) $x_1[n]$ and $x_2[n]$ have equal energies.

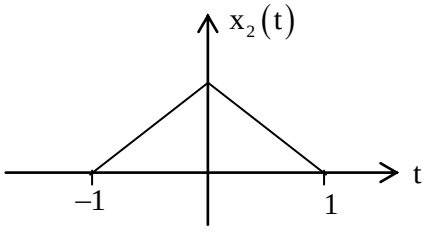
(D) Neither $x_1[n]$ nor $x_2[n]$ is a finite energy signal.

Key: (A)

Exp: Given

$$x_1(t)=\begin{cases}|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases} \qquad x_2(t)=\begin{cases}1-|t|, & -1\le t\le 1\\ 0, & \text{otherwise}\end{cases}$$





$$x_1[n]=\{+1,+0.75,+0.5,0.25,\underset{\uparrow}{0},0.25,0.5,0.75,1\}$$

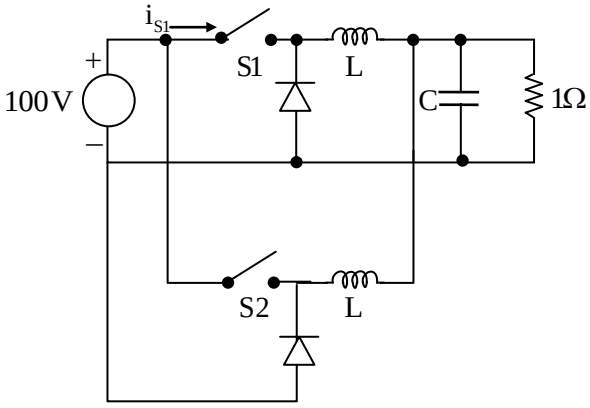
$$x_2[n]=\{0,0.25,0.5,0.75,\underset{\uparrow}{1},0.75,0.5,0.25,0\}$$

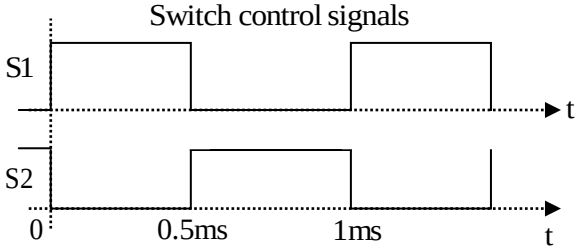
We can see clearly, $x_1[n]$ has greater energy than $x_2[n]$

Energy in $x_1[n]=2\times1^2+2\times(0.75)^2+2\times(0.5)^2+2\times(0.25)^2+0^2$

Energy in $x_2[n]=2\times0^2+2\times(0.75)^2+2\times(0.25)^2+2\times(0.5)^2+0^2$

49. The figure shows two buck converters connected in parallel. The common input dc voltage for the converters has a value of 100V. The converters have inductors of identical value.





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The load resistance is $1\,\Omega$. The capacitor voltage has negligible ripple. Both converters operate in the continuous conduction mode. The switching frequency is 1kHz, and the switch control signals are as shown. The circuit operates in the steady state. Assuming that the converters share the load equally, the average value of $i_{S1,}$ the current of switch S1 (in Ampere), is _____ (up to 2 decimal places).

Key: (12.5)

Exp: $V_0 = DV_s = 0.5\times100 = 50V$

$$I_0 = \frac{V_0}{R} = \frac{50}{1} = 50A.$$

Sence losser negligible, $P_{in} = P_{out}$

$$V_S F_S = V_{out} I_{out}$$

$$100\times I_S = 50\times 50$$

$$I_S = 25A$$

$$I_{S1} = I_{S2} = \frac{I_s}{2} = 12.5A$$

50. Let $A = \begin{bmatrix} 1 & 0 & -1 \\ -1 & 2 & 0 \\ 0 & 0 & -2 \end{bmatrix}$ and $B = A^3\text{-}A^2\text{-}4A+5I$, where I is the 3×3 identity matrix. The determinant of B is _____ (up to 1 decimal place).

Key: (1)

Exp: Given $A = \begin{bmatrix} 1 & 0 & -1 \\ -1 & 2 & 0 \\ 0 & 0 & -2 \end{bmatrix}$

Characteristic equation A is $|A-\lambda I| = 0$

$$\Rightarrow \begin{vmatrix} 1-\lambda & 0 & -1 \\ -1 & 2-\lambda & 0 \\ 0 & 0 & -2-\lambda \end{vmatrix} = 0$$

By Cayley Hamilton theorem,

$$A^3 - A^2 - 4A + 4I = 0$$
$$\Rightarrow A^3 - A^2 - 4A + 5I = I$$
$$\Rightarrow B = I\,(\text{According to the given question})$$
$$\Rightarrow |B| = |I| = 1$$

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51. A 200V DC series motor, when operating from rated voltage while driving a certain load, draws 10A current and runs at 1000 r.p.m. The total series resistance is $1\,\Omega$. The magnetic circuit is assumed to be linear. At the same supply voltage, the load torque is increased by 44%. The speed of the motor in r.pm (rounded to the nearest integer) is _____.

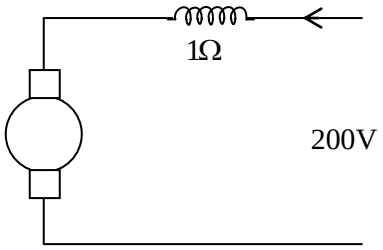
Key: (825)

Exp: 200V, 10A

$(R_a + R_f) = 1\Omega$

$E_{b_1} = V - I_{a_1}(R_a + R_f)$

$= 200 - 10 = 190V$



When torque becomes 1.44 times

$T_2 = 1.44T_1$

Magnetic circuit linear, $\phi \propto I_a$

$T \propto I_a^2 \Rightarrow \frac{T_2}{T_1} - \frac{I_{a_2}^2}{I_{a_1}^2}$

$I_{a_2} = \sqrt{\frac{T_2}{T_1}} \times I_{a_1}$

$= \sqrt{1.44} \times 10 = 12A,$

$E_{b_2} = V - I_{a_2}(R_a + R_f)$

$= 200 - 12 = 188V$

$\frac{E_{b_2}}{E_{b_1}} = \frac{N_2}{N_1} \times \frac{\phi_2}{\phi_1}$

$= \frac{N_2}{N_1} \times \frac{I_{a_2}}{I_{a_1}}$

$N_2 = \frac{E_{b_2}}{E_{b_1}} \times \frac{I_{a_1}}{I_{a_2}} \times N_1 = \frac{188}{190} \times \frac{10}{12} \times 1000$

$= 824.56\,\text{rpm}$

$\simeq 825\,\text{rpm}(\text{nearest integer})$

52. The capacitance of an air filled parallel – plate capacitor is 60pF. When a dielectric slab whose thickness is half the distance between the plates, is placed on one of the plates converting it entirely, the capacitance becomes 86pF. Neglecting the fringing effects, the relative permittivity of the dielectric is _____ (up to 2 decimal places).

Key: (2.53)

Exp: Capacitance, $C_1 = \frac{\varepsilon_0 A}{d/2} = \frac{2\varepsilon_0 A}{d} = 2 \times (60pF) = 120pF$

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and $C_2 = \dfrac{2\varepsilon_0\varepsilon_r A}{d} = (2\times 60)\varepsilon_r \text{pF} = 120\varepsilon_r \text{pF}$

Now, $C_{eq} = \dfrac{C_1 C_2}{C_1 + C_2} = \dfrac{120\times 120\varepsilon_r}{120(1+\varepsilon_r)}$

$$\frac{86}{120} = \frac{\varepsilon_r}{1+\varepsilon_r}$$

or, $\varepsilon_r = \dfrac{86}{34} = 2.53$

53. If C is circle $|z| = 4$ and $f(z) = \dfrac{z^2}{(z^2-3z+2)^2}$. then $\oint_C f(z)dz$ is

(A) 1 (B) 0 (C) -1 (D) -2

Key: (B)

Exp: $f(z) = \dfrac{z^2}{(z^2-3z+2)^2} = \dfrac{z^2}{(z-1)^2(z-2)^2}$

$\Rightarrow z = 1 \& 2$ are poles of order 2, both lie inside $|z| = 4$

Residue of $f(z)$ at $z = 1$

$$\underset{z=1}{\text{Res}}\, f(z) = \frac{1}{(z-1)!}\lim_{z\to 1}\left[\frac{d}{dz}\left\{(z-1)^2\frac{z^2}{(z-1)^2(z-2)^2}\right\}\right]$$

$$= \lim_{z\to 1}\frac{d}{dz}\left(\frac{z^2}{(z-2)^2}\right)$$

$$= \lim_{z\to 1}\frac{(z-2)^2(2z) - z^2.2(z-2)}{(z-2)^4} = 4$$

Residue of $f(z)$ at $z = 2$

$$\underset{z=2}{\text{Res}}\, f(z) = \frac{1}{(z-1)!}\lim_{z\to 2}\left[\frac{d}{dz}\left\{(z-2)^2\frac{z^2}{(z-1)^2(z-2)^2}\right\}\right]$$

$$= \lim_{z\to 2}\frac{d}{dz}\left(\frac{z^2}{(z-1)^2}\right) = -4$$

$\therefore$ By Cauchy Residue theorem, $\oint_C f(z)dz = 2\pi i(4-4) = 0$

54. A dc to dc converter shown in the figure is charging a battery bank. B2 whose voltage is constant at 150 V. B1 is another battery bank whose voltage is constant at 50V. The value of the inductor, L is 5mH and the ideal switch, S is operated with a switching frequency of 5kHz with a duty ratio of 0.4. Once the

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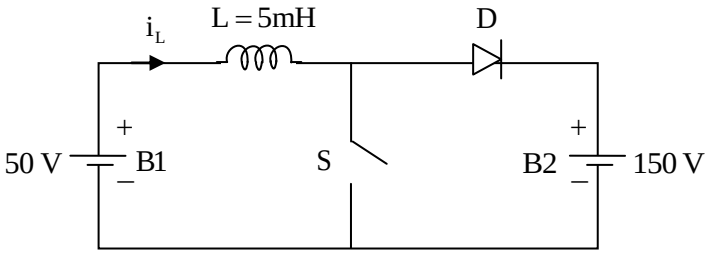
circuit has attained steady state and assuming the diode D to be ideal, the power transferred from B1 to B2 (in Watt) is _____ (up to 2 decimal places)



Key: (12)

Exp: Given $V_{in} = 50V, V_{out} = 150V$

$$\frac{V_0}{V_{in}} = \frac{1}{1-D}$$

$$\frac{150}{50} = \frac{1}{1-D}$$

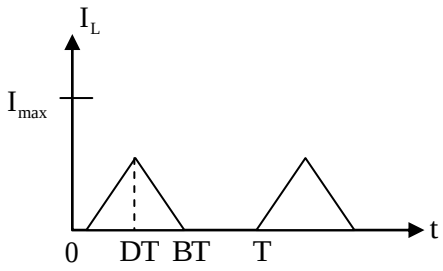
$$D = \frac{2}{3} = 0.666$$

But given duty cycle = 0.4

$\therefore$ The boost converter is operating in discontinuous mode.

$$T = \frac{1}{f} = 200\mu sec$$

$$t_{on} = DT = 80\mu sec.$$



$$V_0 = \left(\frac{\beta}{\beta - D}\right)V_s$$

$$150 = \left[\frac{\beta}{\beta - 0.4}\right]50 \rightarrow \beta = 0.6$$

$$V_S = L\frac{di}{dt} = L\frac{\Delta I}{t_{on}}$$

$$50 \times 5 \times 10^{-3} \times \frac{\Delta I}{80 \times 10^{-6}} \Rightarrow \Delta I = 0.8A$$

$$\Delta I = I_{max} - I_{min} \quad (\because I_{min} = 0)$$

$$\Delta I = I_{max}$$

$$I_{L(avg)} = \frac{\frac{1}{2}I_{max}(\beta T)}{T} = \frac{\frac{1}{2} \times 0.8 \times \left[0.6 \times 200 \times 10^{-6}\right]}{200 \times 10^{-6}} = 0.24A$$

Power transfered from B_1 to $B_2 = V_{in} I_{L(avg)} = 50 \times 0.24 = 12W$

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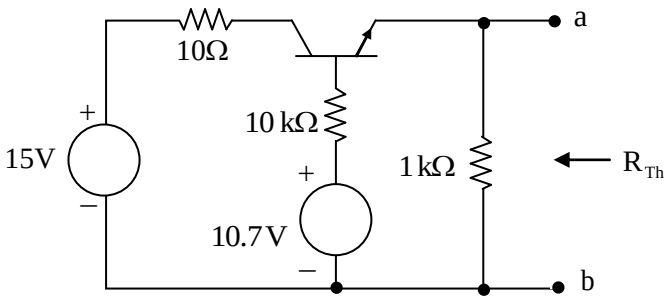
55. In the circuit shown in the figure, the bipolar junction transistor (BJT) has a current gain $\beta = 100$. The base-emitter voltage drop is a constant, V_{BE}=0.7V. The value of the Thevenin equivalent resistance R_{th} (in Ω) as shown in the figure is _____ (up to 2 decimal places).



Key: (90.9)

Exp: Form BJT amplifier, R_{Th} can be written as

$$R_{Th} = \frac{V_{Th}}{I_{SC}} = \frac{V_{OC}}{I_S} \quad [\because \text{it have dependent sources}]$$

$$10.7 - 0.7 - 10kI_B - 1k(\beta+1)I_B = 0$$

$$I_B = \frac{10}{10k + 101k} = \frac{10m}{111}$$

$$V_{OC} = I_E \times 1k = \frac{(1+\beta)}{111} \times 10m \times 1k$$

$$I_B = \frac{10.7 - 0.7}{10k} = \frac{10}{10k} = 1m$$

$$I_{SC} = (1+\beta)I_B = (101)1m$$

$$R_{Th} = \frac{10 \times 1k}{111} = 90.09\Omega$$

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